

ETCHING METHOD AND PLASMA PROCESSING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based on and claims priority from Japanese Patent Application No. 2020-163637, filed on September 29, 2020, with the Japan Patent Office, the disclosure of which is incorporated herein in its entirety by reference.

TECHNICAL FIELD

[0002] The present disclosure relates to an etching method and a plasma processing apparatus.

BACKGROUND

[0003] Japanese Patent Laid-Open Publication No. 2010-041028 discloses a substrate processing method. A processing target layer, an intermediate layer, and a mask layer are stacked on a substrate in this order, and the mask layer has an opening for exposing a portion of the intermediate layer. Deposits are deposited on the side wall surface of the opening of the mask layer by plasma generated from a deposition gas with a gas attachment coefficient S of 0.1 to 1.0. Accordingly, the opening width of the opening is narrowed.

SUMMARY

[0004] According to an aspect of the present disclosure, an etching method ~~includes~~comprising: (a) providing a substrate including a silicon-containing film on a substrate support in a chamber of a plasma processing apparatus; (b) adjusting a temperature of the substrate support to -20 °C or lower; (c) supplying a processing gas including a nitrogen-

containing gas, into the chamber; (d) etching the silicon-containing film by using plasma generated from the processing gas, so that a recess is formed, and a by-product containing silicon and nitrogen adheres to a side wall of the recess; and (e) before (b), setting at least one etching parameter of the temperature of the substrate support and a flow rate of the nitrogen-containing gas included in the processing gas, to adjust a width of a bottom of the recess according to an adhesion amount of the by-product.

[0004a] In another aspect, there is provided an etching method comprising:

(a) providing a substrate including a film containing silicon and nitrogen on a substrate support in a chamber of a plasma processing apparatus;

(b) adjusting a temperature of the substrate support to -20 °C or lower;

(c) supplying a processing gas including hydrogen and fluorine, into the chamber;

(d) etching the film containing silicon and nitrogen by using plasma generated from the processing gas, so that a recess is formed, and a by-product containing silicon and nitrogen adheres to a side wall of the recess; and

(e) before (b), setting the temperature of the substrate support to adjust a width of a bottom of the recess according to an adhesion amount of the by-product.

[0005] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative ~~aspects, embodiments, examples~~ and features described above, further ~~aspects, embodiments, examples~~ and features will become apparent by reference to the drawings and the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. 1 is a partially enlarged cross-sectional view of an example of a substrate to which an etching method according to an embodiment is applicable.

[0007] FIG. 2 is a view schematically illustrating a plasma processing apparatus according to an embodiment.

[0008] FIG. 3 is a flowchart of an etching method according to an embodiment.

[0009] FIGS. 4A to 4C are partially enlarged cross-sectional views of an example of a substrate to which the etching method illustrated in FIG. 3 is applied.

[0010] FIG. 5 is a graph illustrating an example of a correlation between a flow rate of NF_3 gas in a processing gas and a width of the bottom of a recess formed in a silicon-containing film.

[0011] FIG. 6 is a graph illustrating an example of a correlation between a temperature of a substrate support and a width of the bottom of the recess formed in the silicon-containing film.

WHAT IS CLAIMED IS:

1. An etching method comprising:
 - (a) providing a substrate including a silicon-containing film on a substrate support in a chamber of a plasma processing apparatus;
 - (b) adjusting a temperature of the substrate support to -20 °C or lower;
 - (c) supplying a processing gas including a nitrogen-containing gas, into the chamber;
 - (d) etching the silicon-containing film by using plasma generated from the processing gas, so that a recess is formed, and a by-product containing silicon and nitrogen adheres to a side wall of the recess; and
 - (e) before (b), setting at least one etching parameter of the temperature of the substrate support and a flow rate of the nitrogen-containing gas included in the processing gas, to adjust a width of a bottom of the recess according to an adhesion amount of the by-product.
2. The etching method according to claim 1, wherein a setting value of the at least one etching parameter is determined by using a correlation between the width of the bottom of the recess and the at least one etching parameter.
3. The etching method according to claim 2, wherein a setting value of the temperature of the substrate support is determined by using the correlation.
4. The etching method according to claim 2-~~or 3~~, wherein a setting value of the flow rate of the nitrogen-containing gas is determined by using the correlation.
5. The etching method according to ~~any one of claims 1 to 4~~claim 1, further comprising:
 - (f) etching a film included in the substrate by using the silicon-containing film in which the

recess is formed.

6. The etching method according to claim 5, wherein in (f), the film is etched at a temperature lower than a volatilization temperature of the by-product.

7. The etching method according to ~~any one of claims 1 to 6~~claim 1, wherein the substrate further includes a mask having an opening, on the silicon-containing film, and

the etching method further comprises:

(g) measuring an opening width of the mask before (a);

(h) comparing a measured value of the opening width of the mask with a setting value of the opening width of the mask;

(i) when the measured value exceeds the setting value, calculating a difference between the measured value and the setting value; and

(j) determining a setting value of the at least one etching parameter based on the difference.

8. The etching method according to ~~any one of claims 1 to 7~~claim 1, wherein the silicon-containing film is an antireflection film.

9. The etching method according to ~~any one of claims 1 to 8~~claim 1, wherein an aspect ratio of the recess is 5 or less.

10. The etching method according to ~~any one of claims 1 to 9~~claim 1, wherein the nitrogen-containing gas includes at least one of N_2 , NF_3 , and NH_3 .

11. The etching method according to ~~any one of claims 1 to 10~~claim 1, wherein the processing gas includes carbon and fluorine.

12. The etching method according to claim 11, wherein the processing gas includes at least one of a gas mixture of hydrocarbon gas and a fluorine-containing gas, fluorocarbon gas, and hydrofluorocarbon gas.

13. An etching method comprising:

(a) providing a substrate including a film containing silicon and nitrogen on a substrate support in a chamber of a plasma processing apparatus;

(b) adjusting a temperature of the substrate support to -20 °C or lower;

(c) supplying a processing gas including hydrogen and fluorine, into the chamber;

(d) etching the film containing silicon and nitrogen by using plasma generated from the processing gas, so that a recess is formed, and a by-product containing silicon and nitrogen adheres to a side wall of the recess; and

(e) before (b), setting the temperature of the substrate support to adjust a width of a bottom of the recess according to an adhesion amount of the by-product.

~~14. A plasma processing apparatus comprising:~~

~~— a chamber;~~

~~— a substrate support configured to support a substrate including a silicon-containing film in the chamber;~~

~~— a gas supply configured to supply a processing gas used for etching the silicon-containing film and including a nitrogen-containing gas, into the chamber;~~

~~— a plasma generator configured to generate plasma from the processing gas in the chamber;~~

~~and~~

~~— a controller;~~

~~— wherein the controller is configured to adjust a temperature of the substrate support to—~~

~~20 °C or lower, and control at least one of the substrate support and the gas supply such that at least one etching parameter of the temperature of the substrate support and a flow rate of the nitrogen-containing gas included in the processing gas become a setting value;~~

~~—— a by-product containing silicon and nitrogen is generated by etching the silicon-containing film, and adheres to a side wall of a recess formed by etching the silicon-containing film, and~~

~~—— the setting value is set to adjust a width of a bottom of the recess according to an adhesion amount of the by-product.~~

~~15. — The plasma processing apparatus according to claim 14, wherein the substrate support includes a plurality of regions capable of being heated to different temperatures from each other.~~

~~16. — The plasma processing apparatus according to claim 14 or 15, further comprising:~~

~~—— an observation room configured to observe the substrate.~~

14. The etching method according to claim 5, wherein in (f), the film is etched at a temperature equal to or lower than 100 °C.

15. The etching method according to claim 1, wherein in (e), a pressure of the chamber is set to 10 mTorr or more and 100 mTorr or less.

16. The etching method according to claim 1, wherein the substrate includes a mask provided with an opening on the silicon-containing film and made of an organic material or a metal-containing material.

17. The etching method according to claim 1, wherein the processing gas includes at least one of H₂, hydrogen fluoride (HF), hydrocarbon, hydrofluorocarbon, and NH₃ as hydrogen containing molecules.